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Research performed to find substitutes for cleaners and sealants currently used in the LACV-30. Based on the results, recommendations are made for sealants and cleaners which will withstand the LACV-30's marine environment. Report includes appendices of test procedures.

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PREFACE

In the fall of 1986, the Marine Division of the Logistics Support Directorate, Belvoir Research, Development and Engineering Center, formally requested the Center's Chemistry Research Division, Materials, Fuels, and Lubricants Directorate, to estimate the program cost of replacing sealants currently being used on the Lighter Air Cushion Vehicle, 30-ton payload (LACV-30). After first consulting with soldiers who perform the LACV-30 maintenance, and then conducting a physical survey of the craft, the following problems surfaced:

- Corrosion within the electrical system was the prime maintenance problem;
- Cleaning materials and procedures were inadequate;
- Abrasion resistance of the polysulfide base sealants was insufficient;
- Tack/cure time of the polysulfide base sealants was considered too long; and
- The sealants did not prevent corrosion of the cadmium plated bolts used on the craft.

After briefing the Directorate of Maintenance, US Army Troop Support Command (TROSCOM), St. Louis, MO, of the LACV-30's corrosion problems, the task of researching substitutes for those sealants and solvents presently in use commenced.

This report contains the research to improve the corrosion resistance and maintainability of the LACV-30 and other equipment exposed to a marine environment. The project was divided into six groups:

- Market Survey of Products
- Outdoor Exposure
- Indoor Exposure
- Tack/Cure Testing
- Cleaner Testing
- Data Analysis.

Analysis of these six groups resulted in recommending cleaners which would withstand the marine environment of the LACV-30.

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SECTION I. EXPERIMENTAL PROCEDURE

APPROACH

A market survey was initially conducted for possible replacement of sealants presently being used in *wet assembly* and *faying surfaces*. A second market survey was conducted to find a replacement for the Methyl Ethyl Ketone (MEK) and polysulfide solvents presently in use. A third survey was conducted to find a biodegradable waterless or cold water detergent that could be used in the general wash down of the LACV-30.

The second phase of the program involved laboratory testing on products received from the market survey. The tests simulated the marine environment of the LACV-30.

The third phase of the program involved evaluating test results and making recommendations for replacement products to be used in the field.

TESTS PERFORMED

Sealants tested as replacements for the wet assembly underwent three test runs:

1. Tack/Cure Test (see Appendix A)

2. Outdoor Exposure (see Appendices B and C)

3. Indoor Exposure (see Appendices D and C)

Materials used and panel preparation of indoor and outdoor exposures are shown in Appendix E.

Sealants tested for use on faying surfaces underwent two test runs:

1. Tack/Cure Test (see Appendix A)

2. Mating Surface Test (see Appendix F)

The solvents considered as replacements for the polysulfide solvents were tested in accordance with the Polysulfide Solvent Test (see Appendix G). The commercial cleaners, in order to be considered, were tested as described in the Cleaner Test (see Appendix H).

SECTION II. TEST RESULTS

WET ASSEMBLY

From the observations of the test run and the data generated from all products (Figures 1-11), the top rated sealant based solely on corrosion resistance performance was number 4 of the commercial polyurethane caulks (Figure 2). After 21 weeks in the salt spray and 33 weeks outdoors, only slight corrosion was noticed on the area the sealant was protecting. Commercial sealants numbers 12, 13, 33, and 35 had the best tack/cure times with a 1 hour tack time and a 2 to 3 hour cure time.

FAYING SURFACES

From the observations and data gathered on this test for all sealants (Figures 1-10), commercial polyurethane caulk number 4 (Figure 2) was observed to be the most likely to protect a mating area in a marine environment. This caulk is the same product noticed to have the most favorable data for the Wet Assembly Test.

POLYSULFIDE SOLVENTS

From the two solvents tested (Figure 12), PSS-2 outperformed PSS-1 in two out of three tests. PSS-2 can be used as a year-around solvent, while PSS-1 is only effective in a certain temperature range.

CLEANERS

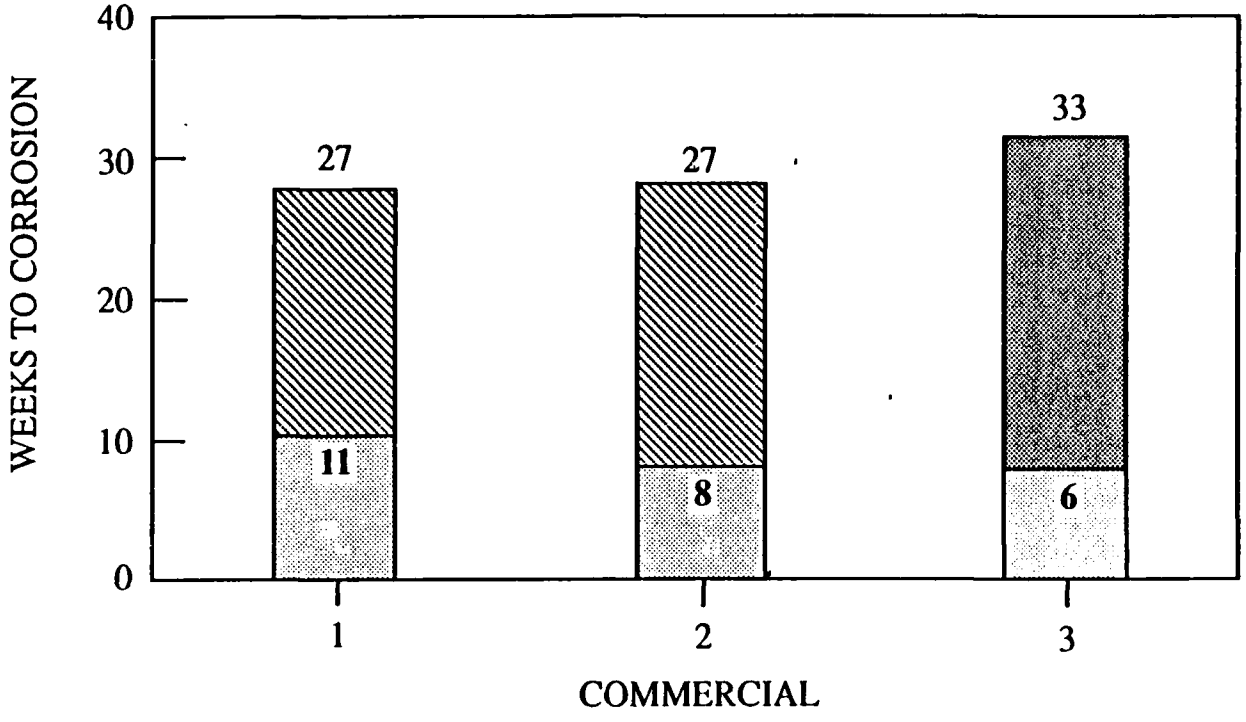
Of the commercial cleaners tested (Figure 13), the following are recognized as the top five: numbers 12, 11, 6, 5, and 9. These cleaners had a film removal of 75 percent and a remaining chlorine content of less than 1 percent.

SECTION III. CONCLUSIONS

- It is concluded from all testing and data that commercial sealant number 4 was the best overall sealant for both wet assembly and faying surfaces. As far as corrosion resistance, number 4 had the best results for both wet assembly and faying. This sealant also had an acceptable tack time of 1 hour and cure time of 10 hours. (Refer to Appendix I for additional cleaner test information).

- The polysulfide solvent data showed that PSS-2 (Figure 12) was the best polysulfide solvent for use on-board the LACV-30.

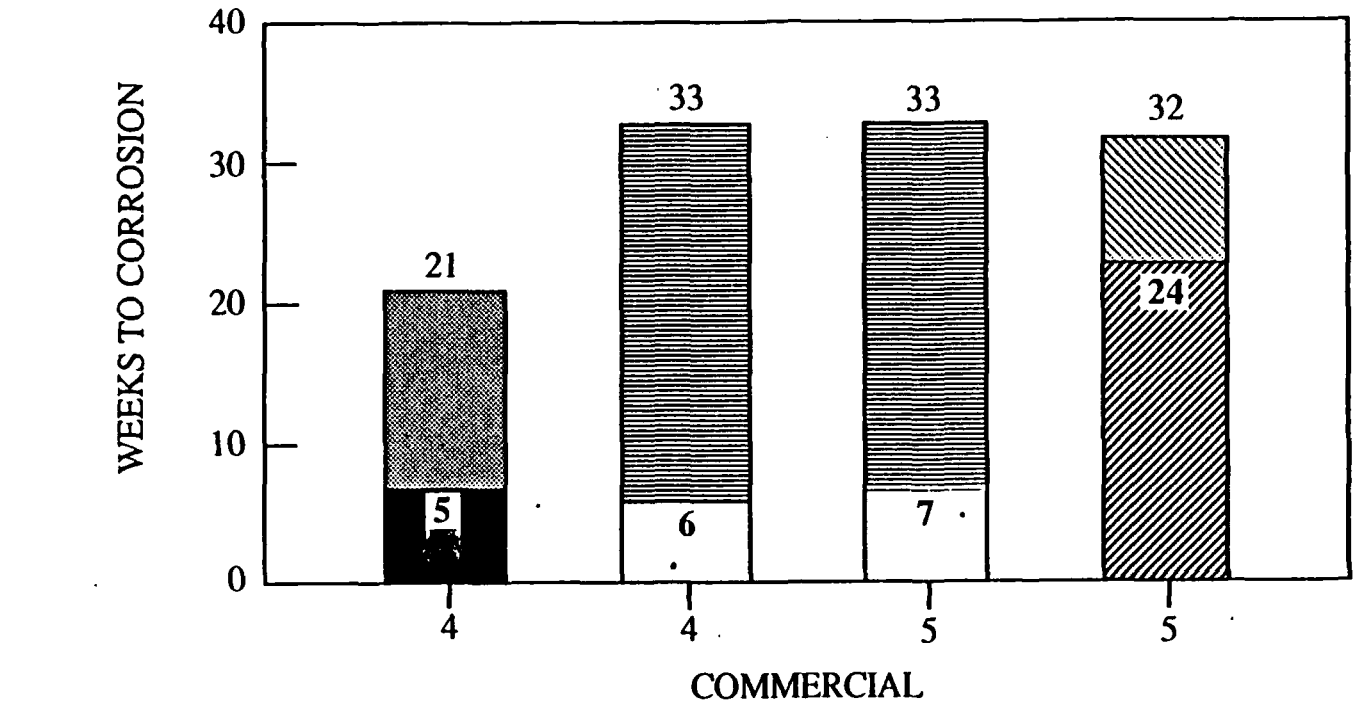
- Of the cleaners tested, the following five had favorable results: numbers 5, 6, 9, 11, and 12 (Figure 13). Out of these five, cleaner number 12 outperformed each of the other four cleaners.



COMMERCIAL	INDOOR HOURS TACK	CURE
1	72	120
2	14	100
3	120	168

NOTE: FAYING AND SALT SPRAY TESTS NOT RUN DUE TO TACK/CURE DATA.

Figure 1. Polyurethane Paints



INITIAL SALT SPRAY

INITIAL FAYING HOT/COLD

INITIAL OUTDOORS

SLIGHT CORROSION FAYING HOT/COLD

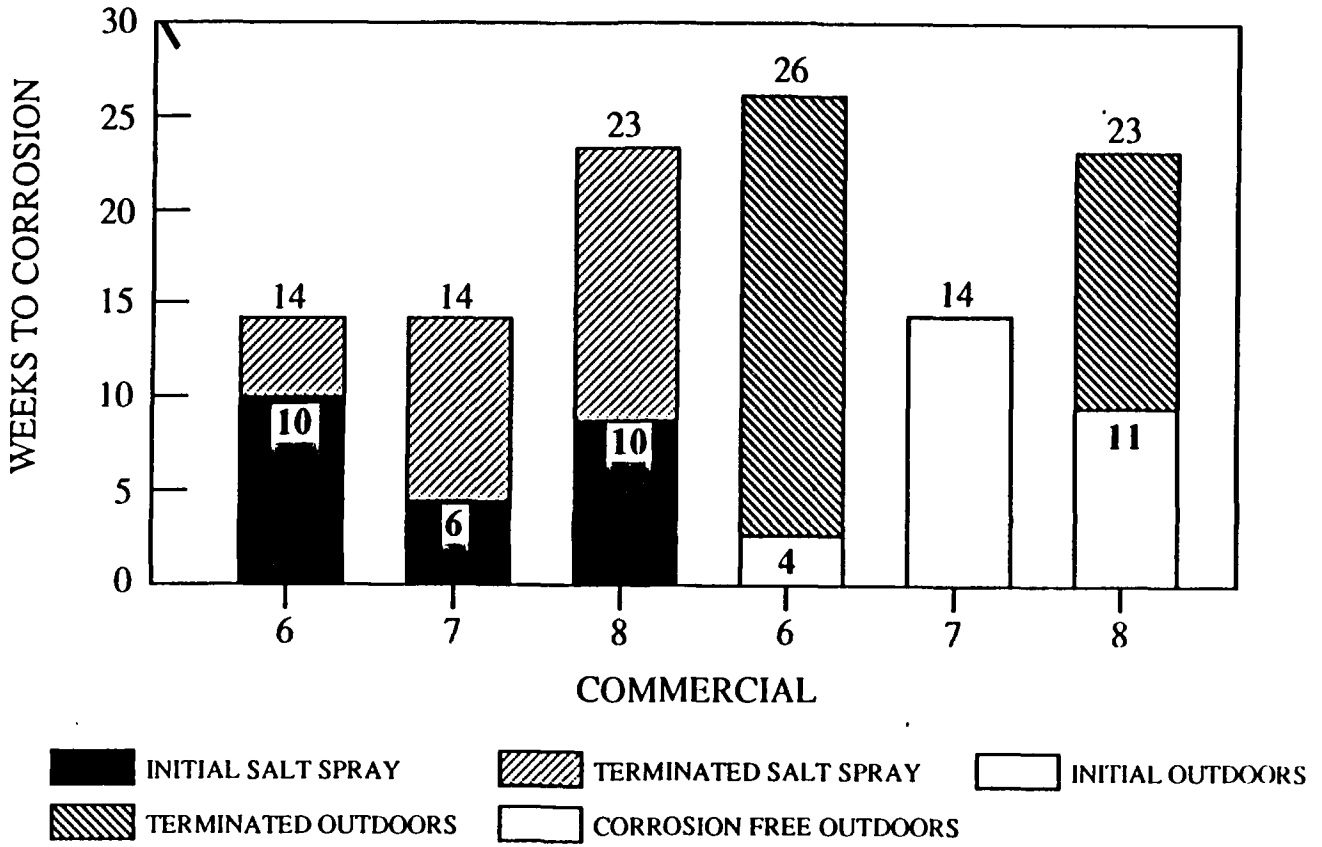
SLIGHT CORROSION SALT SPRAY

SLIGHT CORROSION OUTDOORS

COMMERCIAL	INDOOR HOURS TACK	CURE
4	1	10
5	144	168

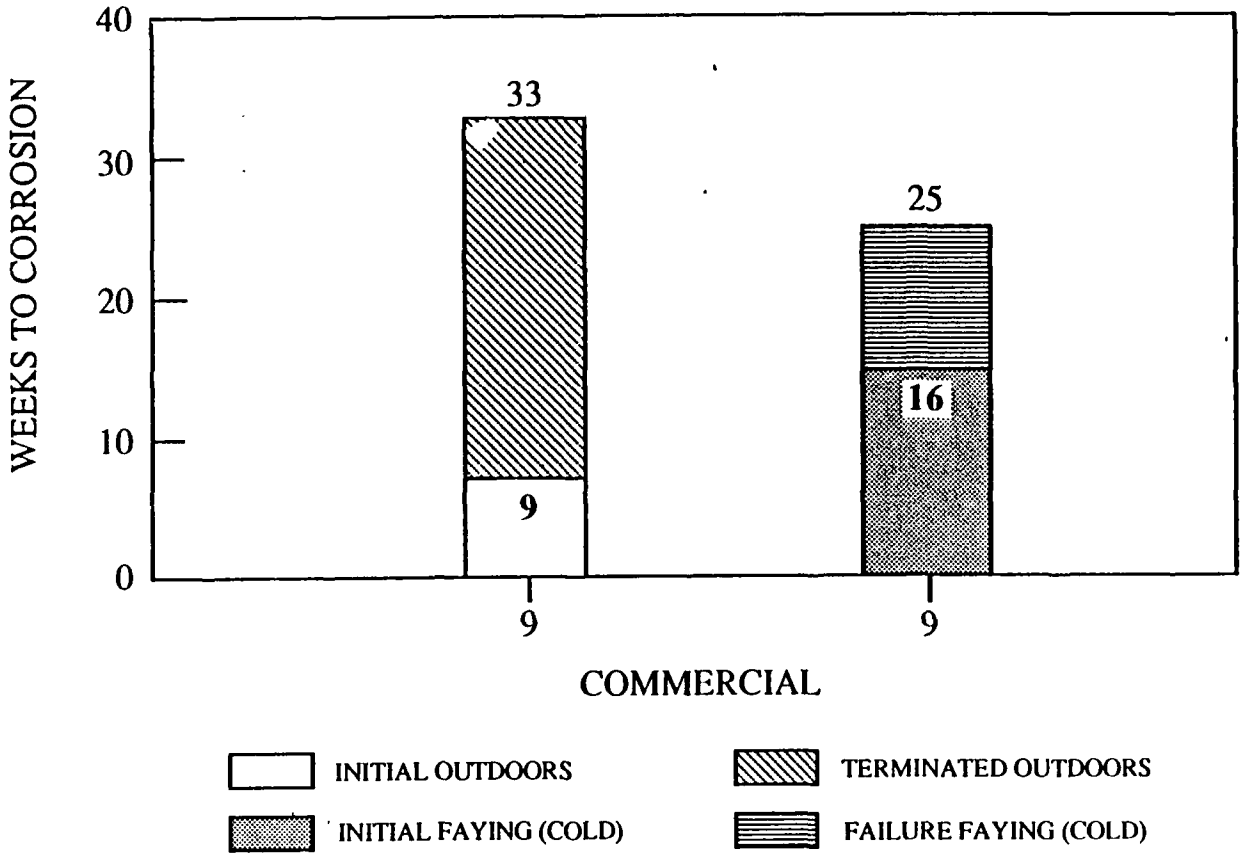
NOTE: FAYING AND SALT SPRAY TESTS
NOT RUN ON COMMERCIAL 5 DUE TO TACK/CURE DATA.

Figure 2. Polyurethane Caulk



NOTE: TACK/CURE AND FAYING TESTS NOT RUN BECAUSE PRODUCT CRACKS UNDER VIBRATION.

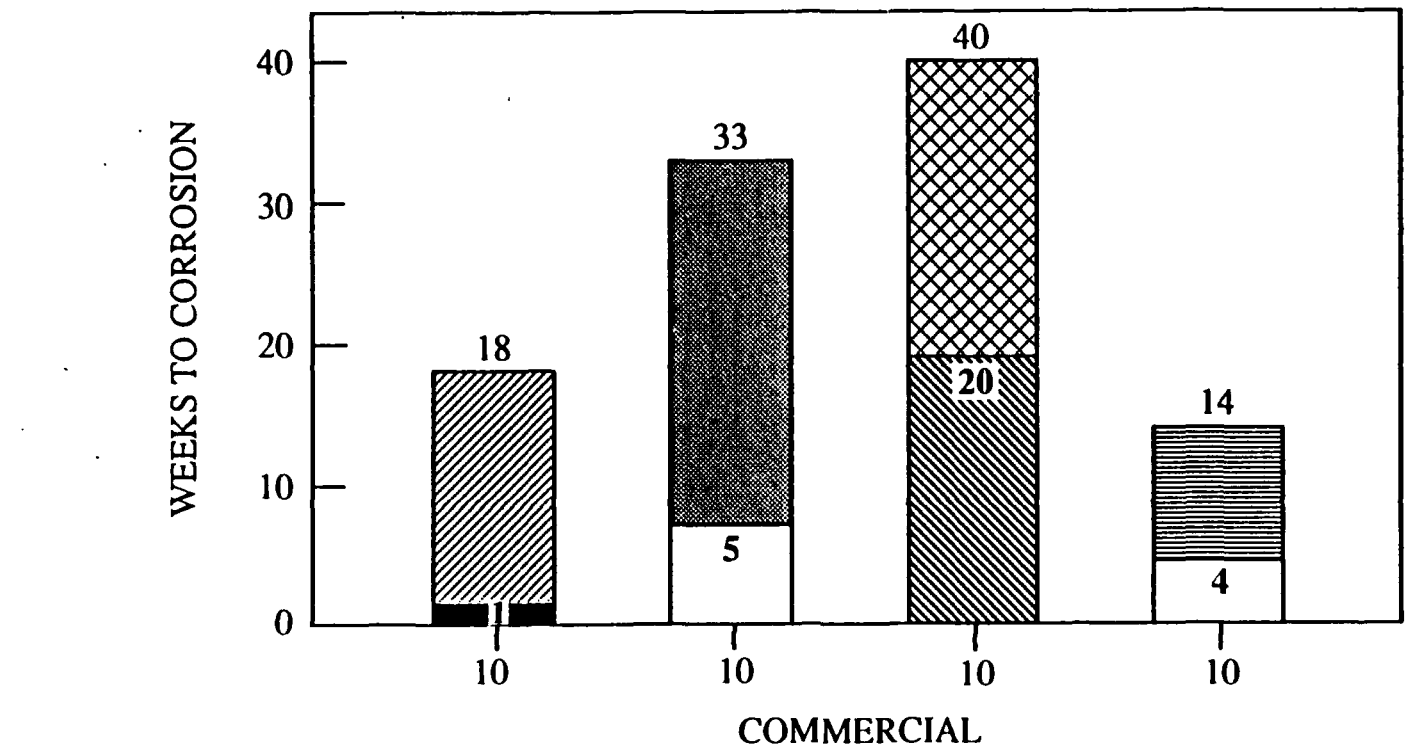
Figure 3. Polysulfide Sealants (2 Components)



NOTE: HOT CURE FAYING TEST NOT RUN DUE TO RESULTS OF COLD CURE FAYING TEST.

	INDOOR HOURS	
COMMERCIAL	TACK	CURE
9	8	SOFT @ 96

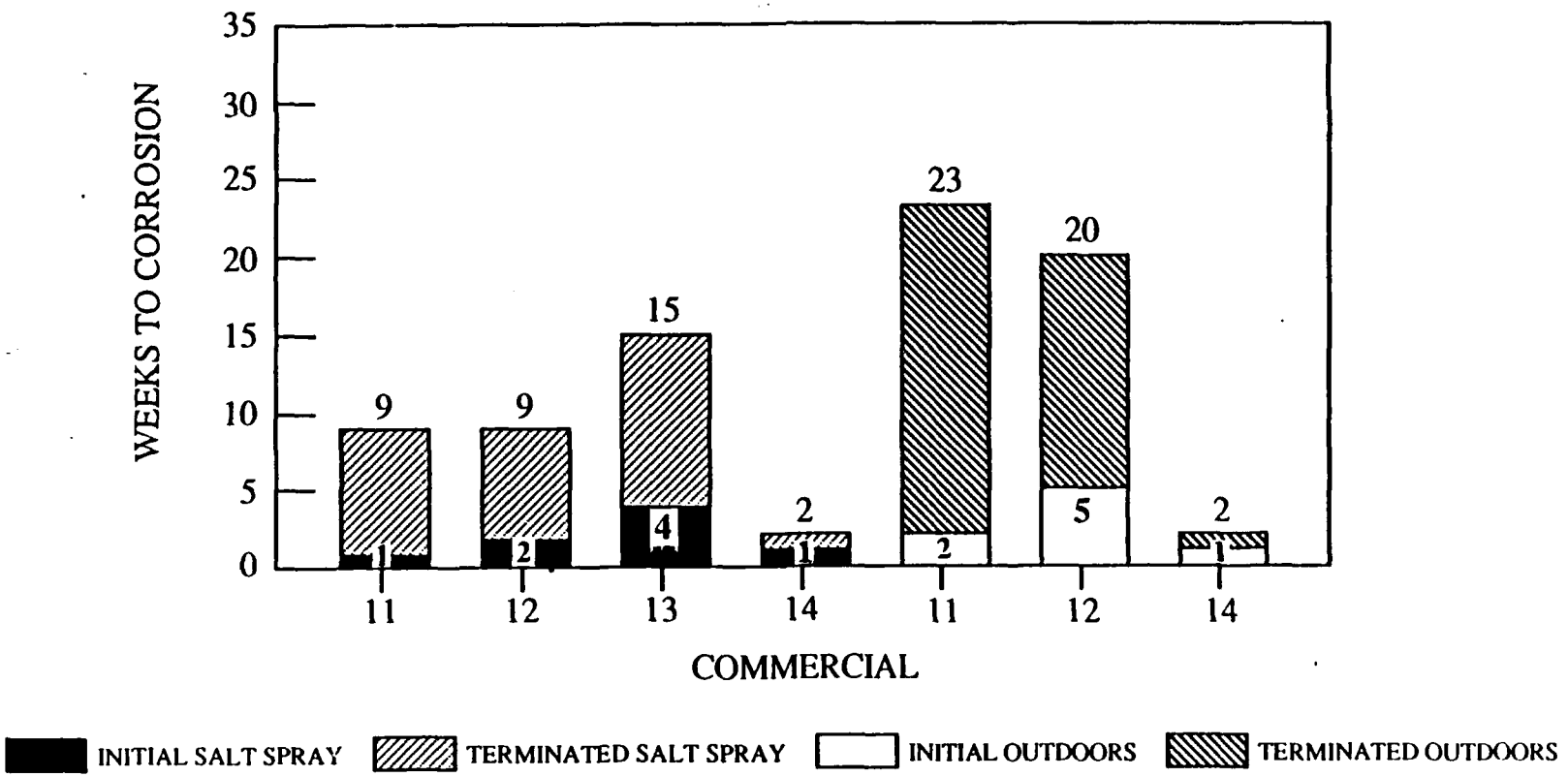
Figure 4. Polysulfide Caulk (1 Component)



INITIAL SALT SPRAY
TERMINATED SALT SPRAY
INITIAL OUTDOORS
INITIAL FAYING (COLD)
FAILURE FAYING (COLD)
INITIAL FAYING (HOT)
SLIGHT CORROSION OUTDOORS
FAILURE FAYING (HOT)

	INDOOR HOURS	
COMMERCIAL	TACK	CURE
10	1	15

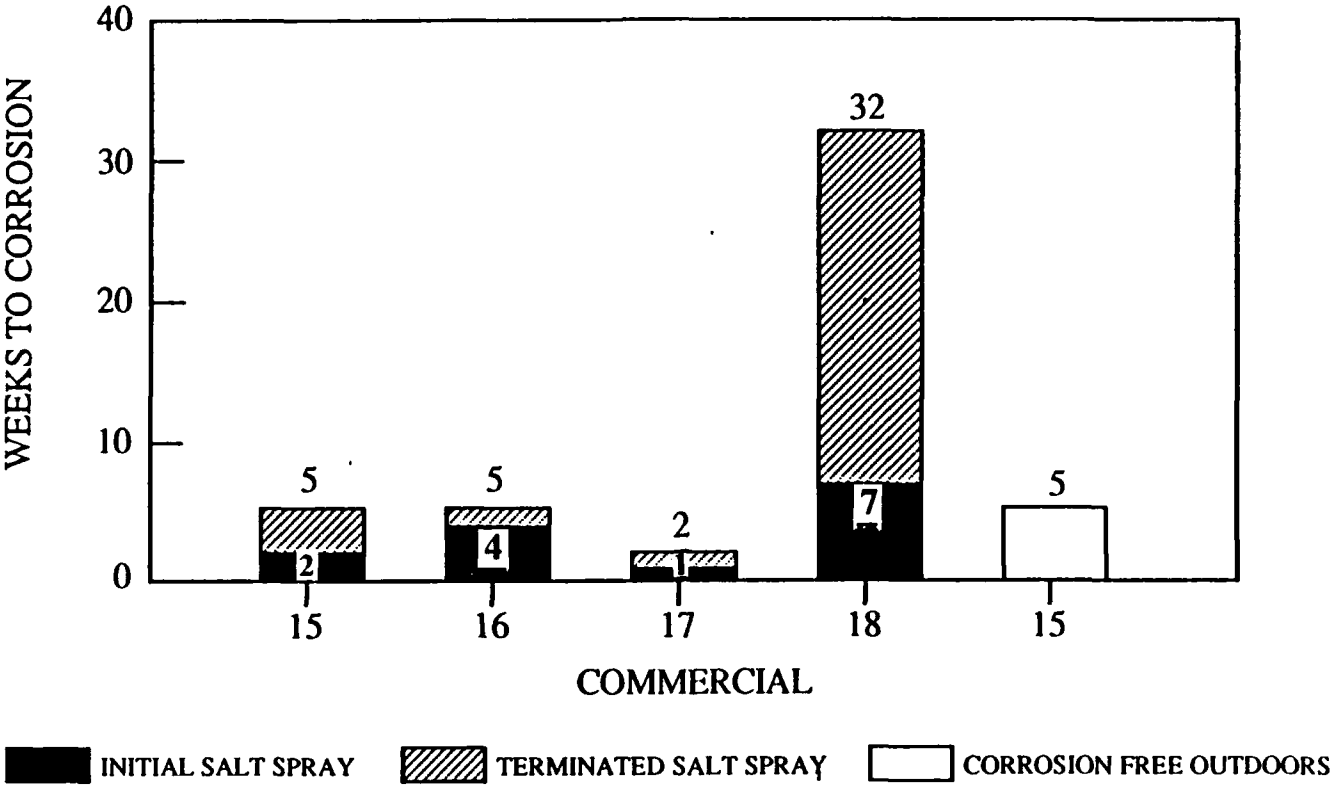
Figure 5. Translucent Caulk



NOTES: FAYING AND TACK/CURE TESTS NOT RUN ON COMMERCIAL 10.
FAYING TEST NOT RUN ON COMMERCIAL 11 DUE TO SALT SPRAY DATA.
OUTDOOR AND FAYING TESTS NOT RUN ON COMMERCIAL 12 DUE TO SALT SPRAY DATA.
FAYING AND TACK/CURE TESTS NOT RUN ON COMMERCIAL 13 DUE TO SALT SPRAY AND OUTDOOR DATA.

	INDOOR HOURS	
COMMERCIAL	TACK	CURE
12	1	3
13	1	2

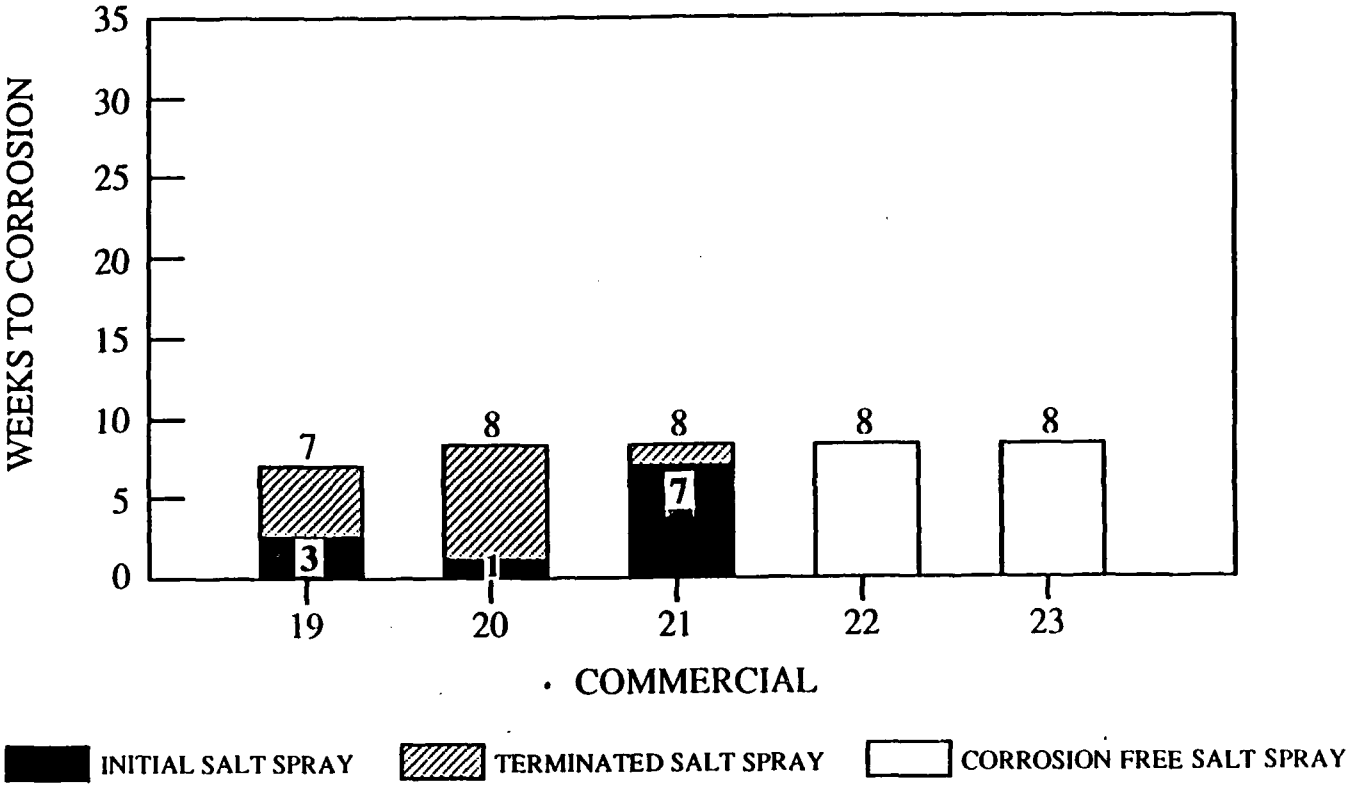
Figure 6. Miscellaneous Sealants (1 of 2)



NOTES: FAYING AND TACK/CURE TESTS NOT RUN ON COMMERCIAL 15 DUE TO SALT SPRAY DATA.
OUTDOOR, FAYING, AND TACK/CURE TESTS NOT RUN ON COMMERCIAL 16 NOR 17 DUE TO SALT SPRAY DATA.
OUTDOOR AND FAYING TESTS NOT RUN ON COMMERCIAL 18 DUE TO TACK/CURE TEST DATA.

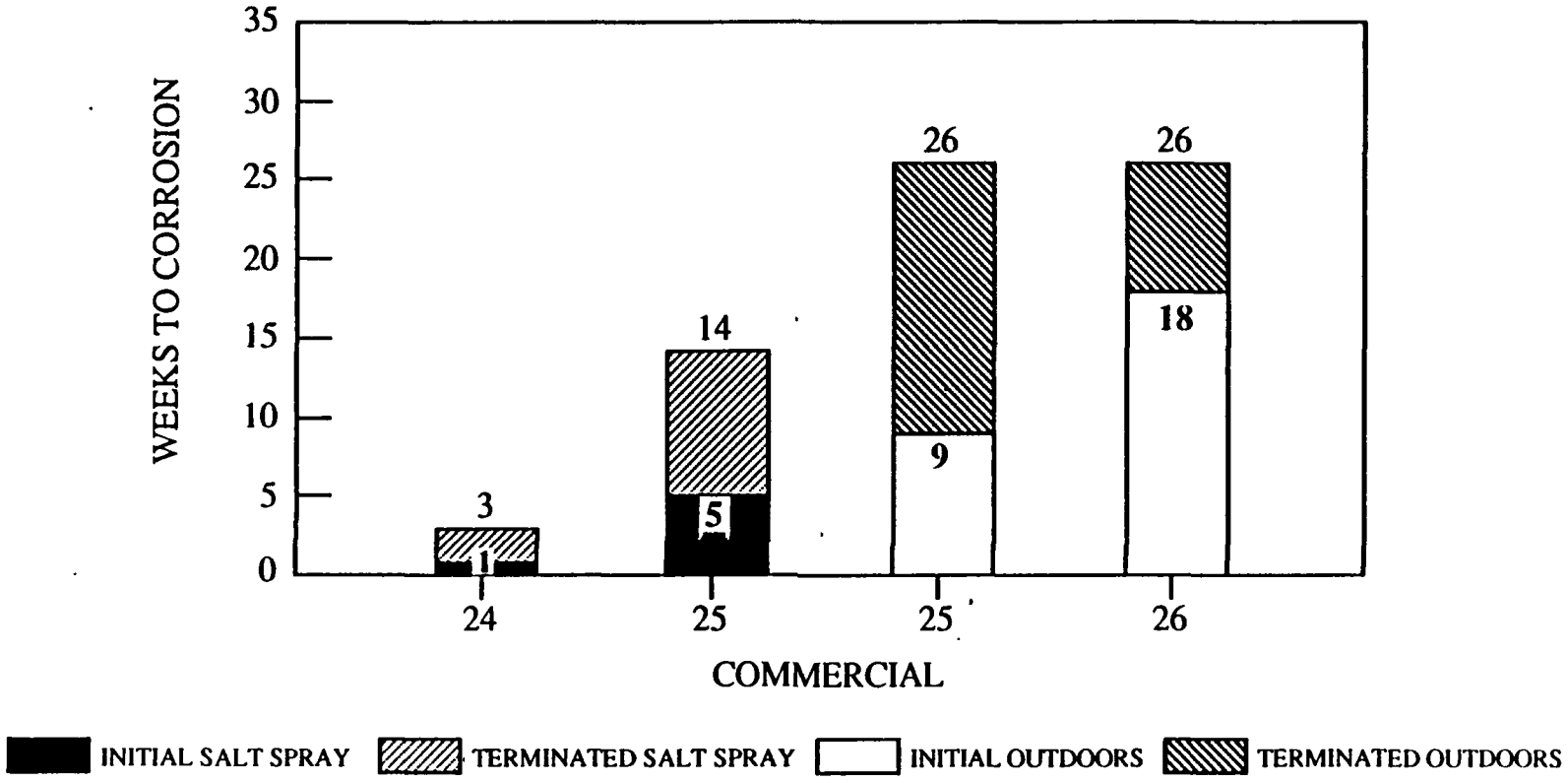
	INDOOR HOURS	
COMMERCIAL	TACK	CURE
18	14	96

Figure 6. Miscellaneous Sealants - Continued (2 of 2)



NOTE: OUTDOOR, FAYING, AND TACK/CURE TESTS NOT RUN BECAUSE PRODUCTS WERE INCOMPATIBLE WITH DEGREASER.

Figure 7. Aerosol Paints



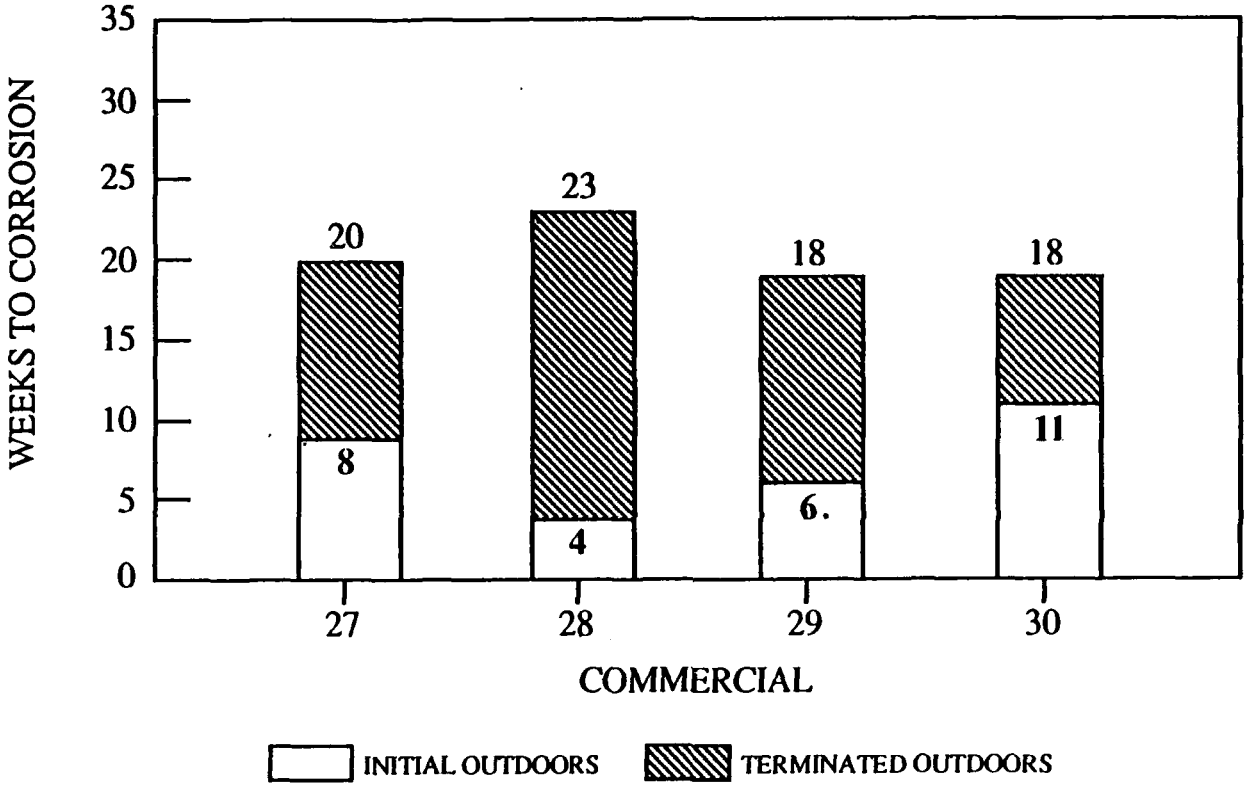
NOTES: OUTDOOR, FAYING, AND TACK/CURE TESTS NOT RUN ON COMMERCIAL 24 DUE TO SALT SPRAY.
FAYING TEST NOT RUN ON COMMERCIAL 25 DUE TO TACK/CURE DATA.
SALT SPRAY AND FAYING TESTS NOT RUN ON COMMERCIAL 26 DUE TO TACK/CURE DATA.

INDOOR HOURS

TACK CURE

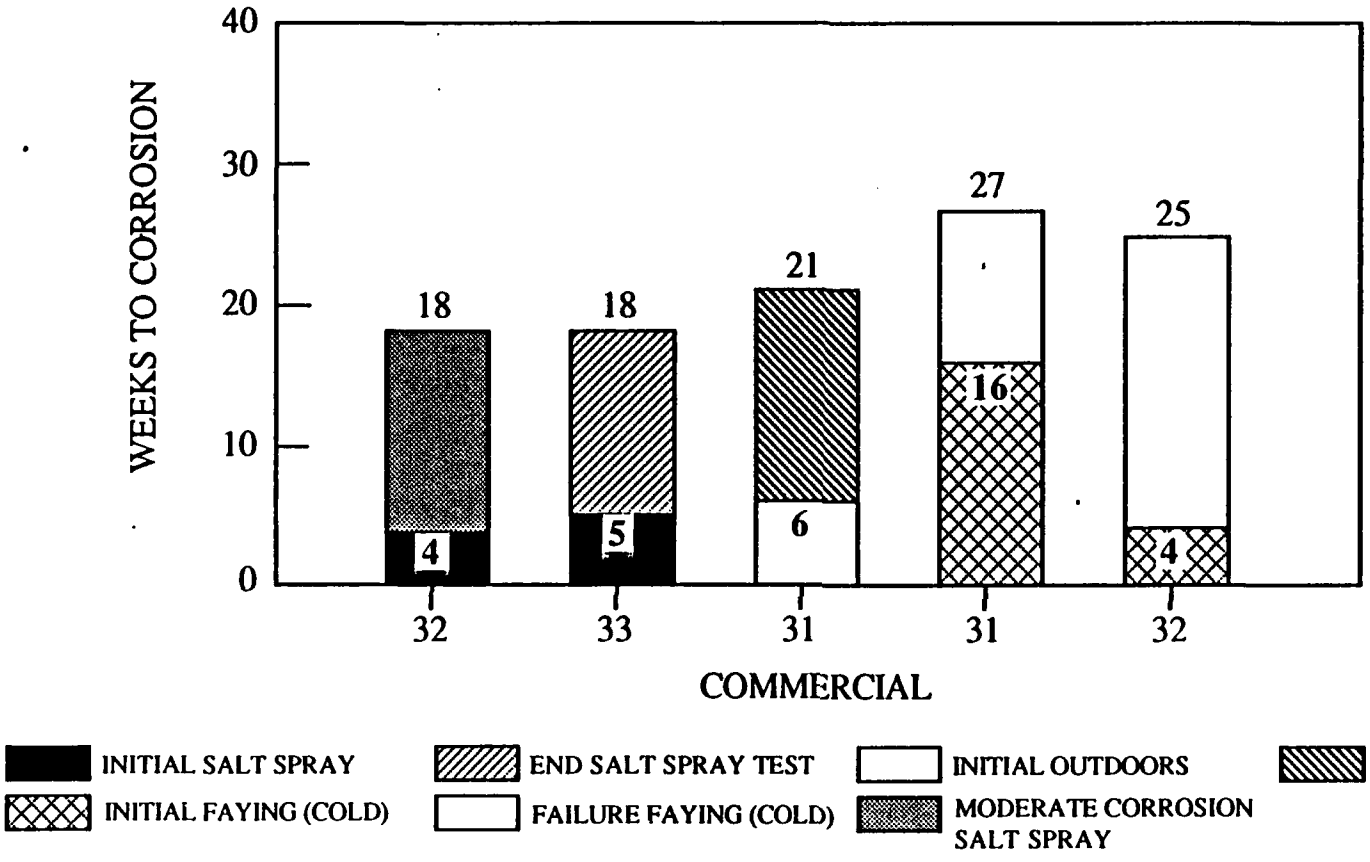
AFTER 120 HOURS COMMERCIAL 25 AND 26 WERE NOT TACK-FREE OR CURED

Figure 8. Thread Sealants



NOTE: SALT SPRAY, FAYING, AND TACK/CURE TESTS NOT RUN DUE TO OUTDOOR DATA.

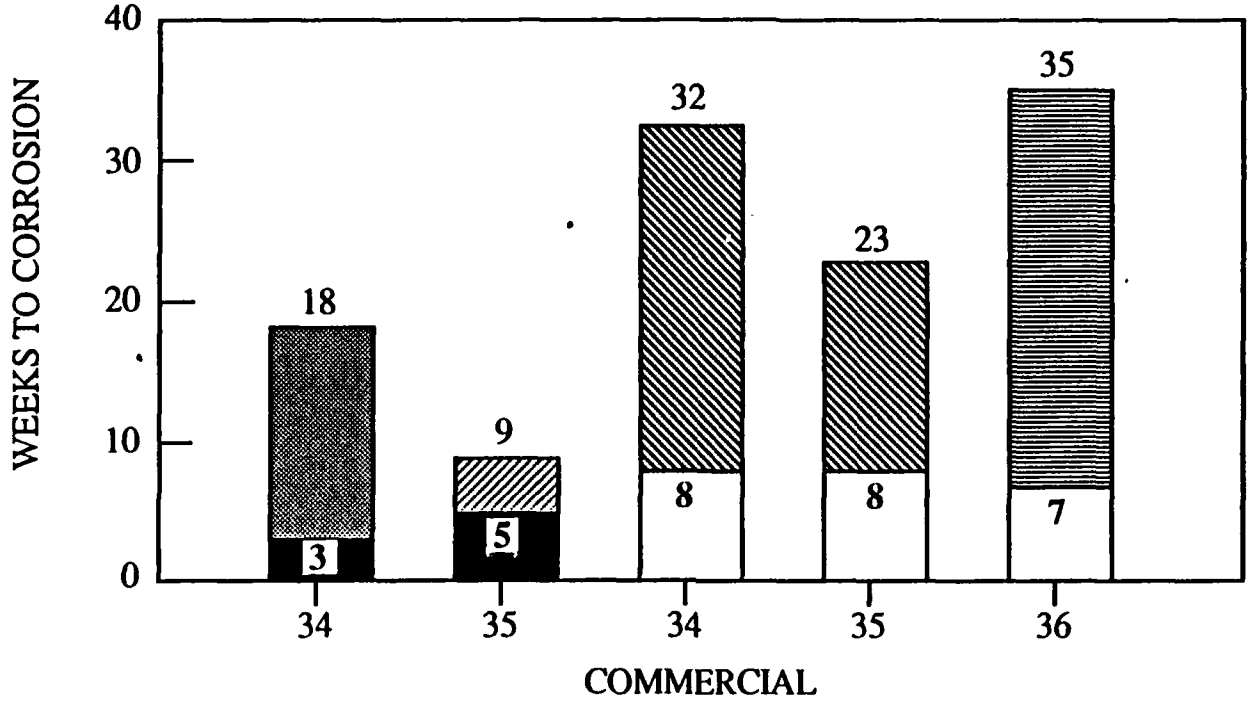
Figure 9. Rust Preventives



NOTES: SALT SPRAY AND FAYING HOT TESTS NOT RUN ON COMMERCIAL 31 DUE TO OUTDOOR DATA
OUTDOOR AND FAYING HOT TESTS NOT RUN ON COMMERCIAL 32 DUE TO TACK/CURE DATA.
OUTDOOR AND FAYING TESTS NOT RUN ON COMMERCIAL 33 DUE TO SALT SPRAY DATA.

	INDOOR HOURS	
COMMERCIAL	TACK	CURE
31	1	36
32	2	DOESN'T CURE
33	1	2

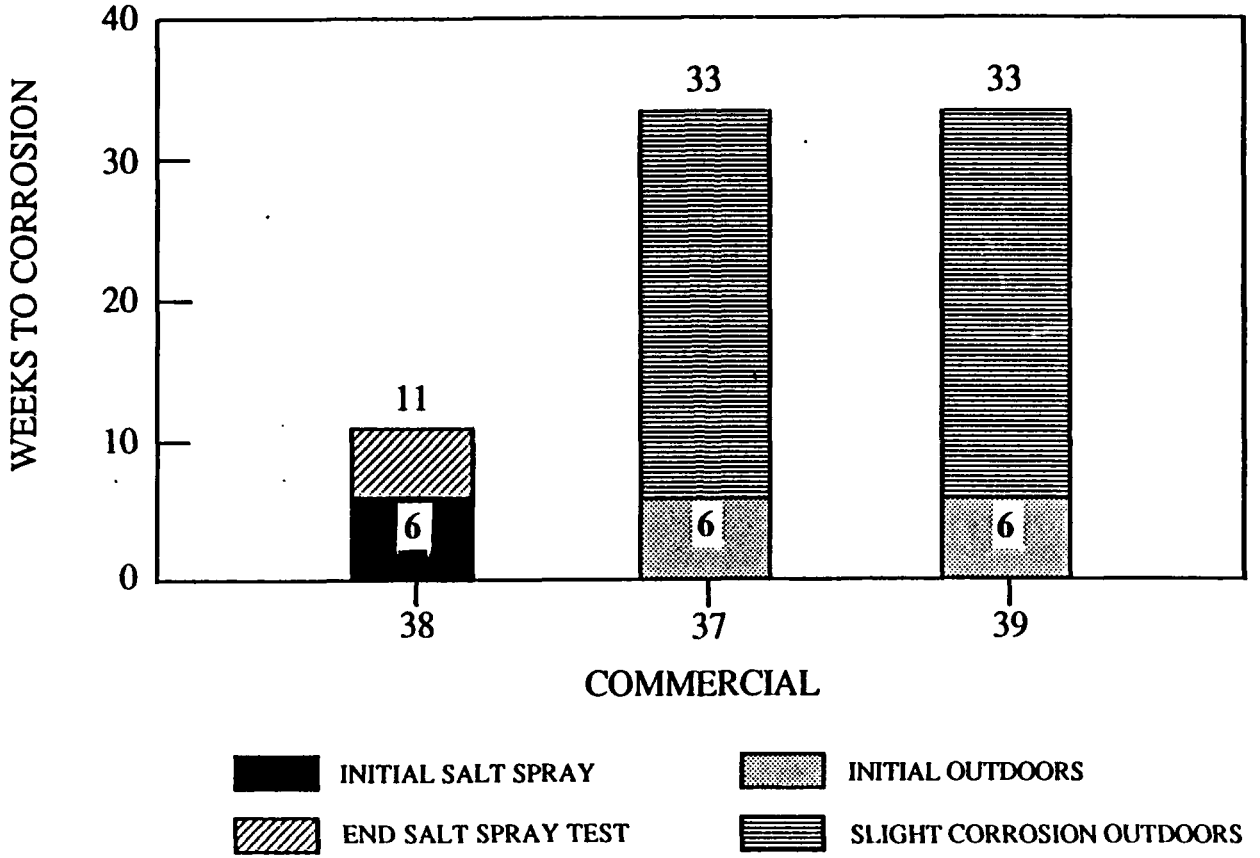
Figure 10. Silicone Sealers (1 of 3)



NOTES: FAYING TEST NOT RUN ON COMMERCIAL 34 DUE TO TACK/CURE DATA.
FAYING TEST NOT RUN ON COMMERCIAL 35 DUE TO SALT SPRAY DATA.
SALT SPRAY AND FAYING TESTS NOT RUN ON COMMERCIAL 36 DUE TO TACK/CURE DATA.

	INDOOR HOURS	
COMMERCIAL	TACK	CURE
34	12	84
35	1	3
36	49	120

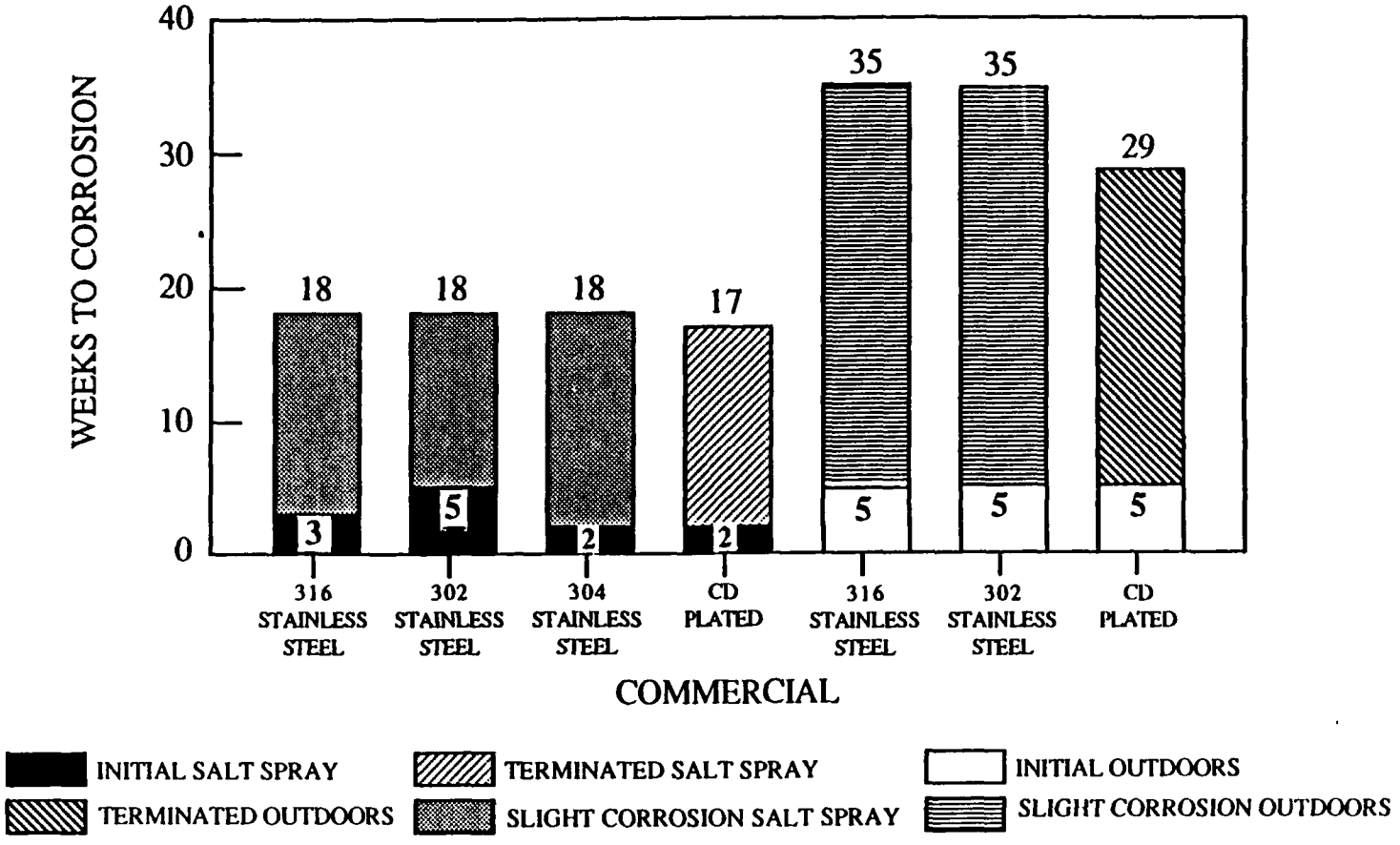
Figure 10. Silicone Sealers - Continued (2 of 3)



COMMERCIAL	INDOOR HOURS TACK	CURE
37	14	96
(39)	1	15

NOTES: SALT SPRAY AND FAYING TESTS NOT RUN ON COMMERCIAL 37 DUE TO TACK/CURE DATA.
OUTDOOR, FAYING, AND TACK/CURE TESTS NOT RUN ON COMMERCIAL 38 DUE TO SALT SPRAY.
SALT SPRAY AND FAYING TESTS NOT RUN ON COMMERCIAL 39.

Figure 10. Silicone Sealers - Continued (3 of 3)



NOTE: OUTDOOR TEST NOT RUN ON 304 STAINLESS STEEL.

Figure 11. Bare Metal Bolts

HOURS OF MAX EFFECTIVENESS/PERCENTAGE LIFTED AT:

SOLVENT	35°F	65°F	95°F
PSS-1	No effect	3 hr/75%	No effect
PSS-2	1 hr/35%	1 hr/50%	1 hr/100%

Figure 12. Polysulfide Sealant Solvent (PSS) Results

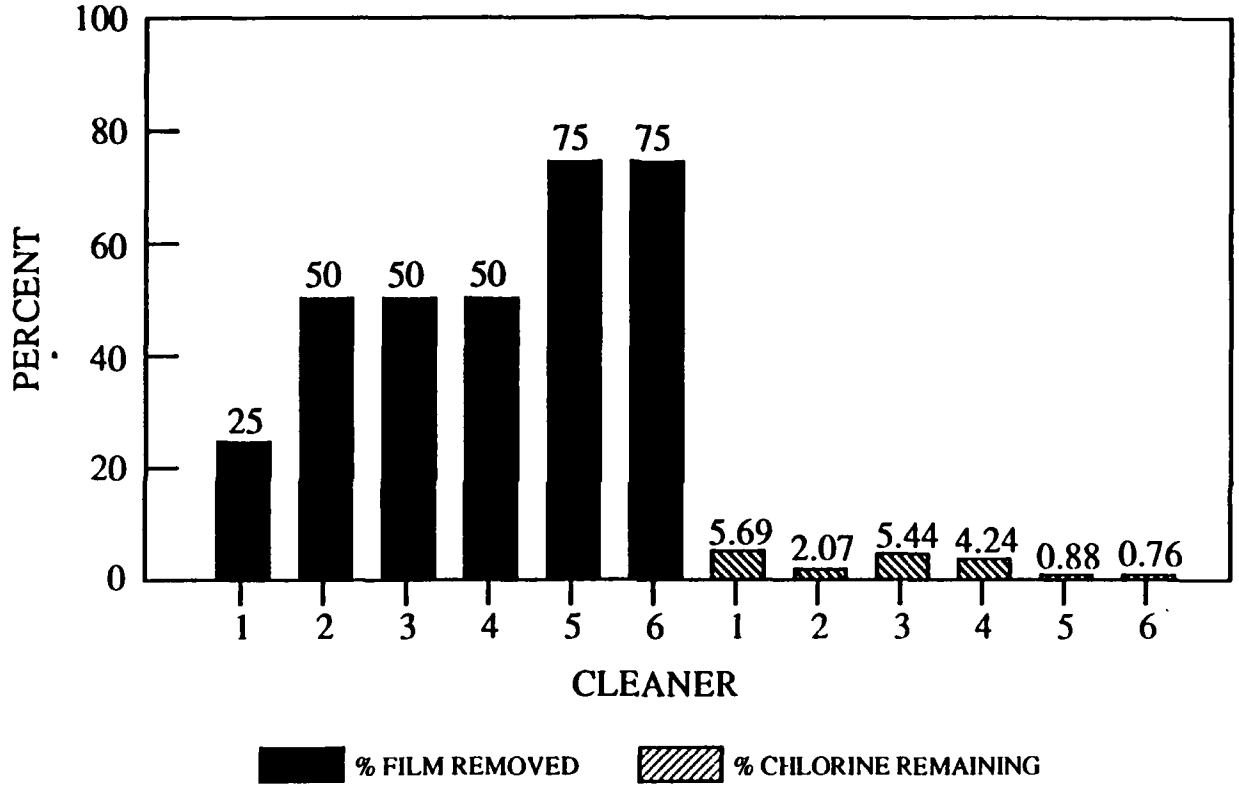


Figure 13. Cleaners (1 of 2)

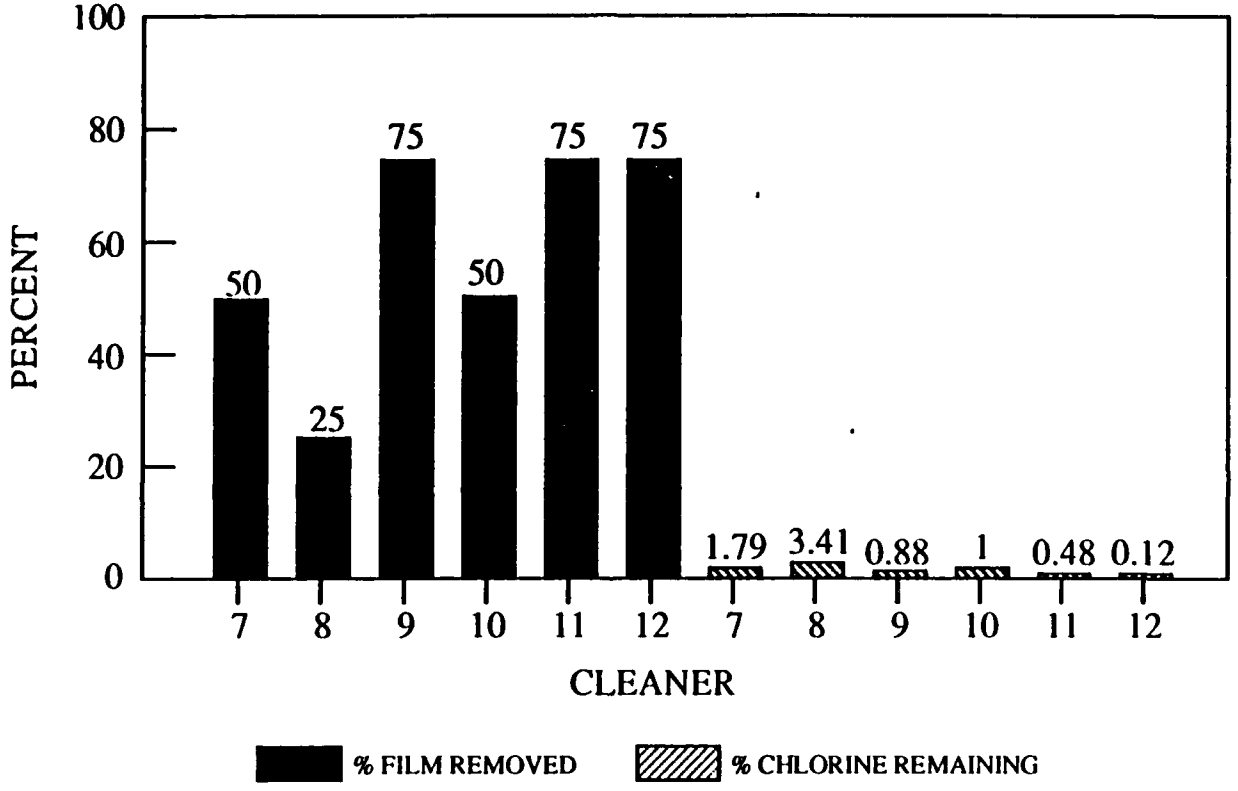


Figure 13. Cleaners - Continued (2 of 2)

APPENDIX A
TACK/CURE TIME TEST PROCEDURE

1. Set cold box to 35°F.

2. Chill test panels overnight, clean with clean cloth and MEK.

3. Apply test materials per instruction sheet, and measure film thickness.

4. Check hourly over a 9-hour period to establish tack free time.

5. The following morning, check those systems not tack-free after 9 hours; if cured, set up to repeat test at end of day to see if tack-free time between 9 and 12 hours.

6. Once tack-free time established, check at 24-hour intervals to establish cure time. No uncured material found.

7. The tack-free state will be determined by gently pressing down on the film surface using a covered forefinger, and not forcing the film surface to break.

8. Determine the he cure time by using either a cake tester, sewing needle or scapel, in descending order of the coating thickness.

9. Apply all samples to the same thickness for all materials tested.

10. Prepare all panels in duplicate for tack/cure test.

APPENDIX B
SEALANT OUTDOOR TEST PROCEDURE

1. Leave preconditioned, precorroded panels outdoors overnight and assemble (refer to Appendix C).

2. Spray twice a week with an acid marine solution (3.5%, pH 4.1).

3. Schedule bolt inspection at 3-week intervals. One bolt from each panel will be removed, inspected, cleaned, and then reassembled.

4. Inspect all panels weekly for any signs of corrosion which will be noted and tracked, but do not remove panels prior to the next scheduled removal date. For a given sealant—

   a. If up to three bolts show signs of corrosion in different panels, remove two bolts at the next scheduled period.

   b. If four or more bolts show signs of corrosion in different panels, remove half at the next scheduled period, and half the following period.

   c. If three or more bolts on a single panel show signs of corrosion, pull all the bolts on that panel at next regular period, and redo the entire panel, providing the other panels in that sealants' test set are relatively corrosion free.

   d. Reporting periods are in 84-day segments from the start date of sealant application.

APPENDIX C
WET ASSEMBLY SEALANT TEST PROCEDURE

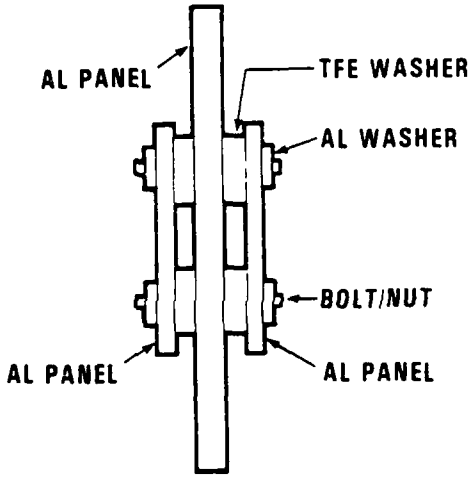
Procedure

1. Using MEK and a clean, lint-free cloth, clean preconditioned, precorroded panels.
2. Completely coat bolts and A1 washers with sealant. Install all hardware per diagrams below and tighten finger-tight.
3. Snug up six bolts with teflon washers.
4. Torque down two bolts to 10 psi for broken film testing.
5. Cure and test per exposure instructions.

Diagram Wet Assembly Sealant

Test panels: precorroded Al 6061-T6

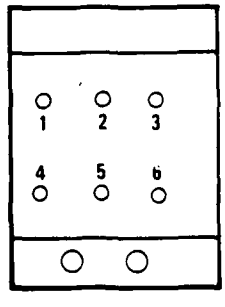
1 each - 4" x 6" panels
2 each - 4" x 3" panels
3 panels = panel set



Controls with Cd plated bolts MIL-S-81733

Panel Assembly Diagram

Four panel sets per exposure with front TFE washer slotted per sealant
Four panel sets per exposure with rear TFE washer slotted per sealant
Four panel sets per exposure of front and rear TFE washers slotted per sealant



RESERVED BROKEN FILM TESTING

Pattern for checking slotted teflon washers

APPENDIX D
SEALANT INDOOR TEST PROCEDURE

1. Leave preconditioned, precorroded panels indoors overnight at 35-40°F and RH > 80%.

2. Clean and assemble (refer to Appendix C).

3. Cure at 35-40°F/RH ≥ 80% for 24 hours.

4. Expose to cyclic salt fog test for 7 days, then wash down panels using tap water and a hose nozzle. Check for signs of corrosion, replace back into the salt spray, and expose for another 7 days; then, wash again.

5. Once cured score film for broken film testing.

6. Schedule bolt removal the same as the outdoor exposure, using the same bolt removal guidelines.

7. Salt Spray Test Cycle:

Spray	1 hour
Purge	2 hours
Soak	3 hours
Total T	6 hours (one cycle); four cycles/day

APPENDIX E
WET ASSEMBLY TEST MATERIALS

Materials

Al 6061-T6 plates and washers

Cd plated carbon steel bolts and nuts

316 stainless steel bolts and nuts

303/304 stainless steel bolts and nuts

18-8 stainless steel bolts and nuts

MIL-S-81733 (Sealing and Coating Compound, Corrosion Inhibitive)

MIL-S-8802 (Sealing Compound, Temperature-Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High-Adhesion)

Methyl Ethyl Ketone (MEK)

Commercial Marine Mix

Tap Water

MIL-C-83360C (Cleaning and Lubricating Compound, Electrical Cleaner).

Panel Preparation

1. Use precorroded panels.

2. Wash off precorroded panels with tap water, using a hose and nozzle. Pressure and stream to be determined.

3. In Room B119, air dry panels and store them in open racks to be used as needed.

4. **For all testing:** Immediately prior to applying a sealant, clean down the panels using a clean cloth wetted with MEK, air dry, and apply wipe in one direction only.

APPENDIX F
MATING SURFACES SEALANT TEST PROCEDURE

1. Controls: MIL-S-8802

2. Materials:

   a. 12 panels per spreadable sealant

   b. 12 panels per dry sealant

   c. 8 bolts per panel

   d. 2 face plates per panel

3. Apply the spreadable sealants to cover the area from the inner diameter of the center hole to the outer diameter of the cover plates.

4. For the tape type sealants, assemble six panels by placing a single line of tape so that all the bolt holes are inside the tape circle, and the top circle lies well within the cover plate's circumference. Assemble the six panels so that the plates' bolt holes lie between two lines of tape.

5. Dip the aluminum in primer at the time of assembly; therefore, they must be chromated in advance, per MIL-C-5541.

6. Expose six panels of the spreadable sealants and all six tape sealants to 140°F for 7 days, cool to room temperature, then chill to 20°F for 48 hours before going into a cyclic salt spray. After one week, wash down with marine mix. Salt spray test cycle:

Salt Spray	1 hour
Purge	2 hours
Soak	3 hours

   Cure the other six sealant panels at 35-40°F, RH ≥ 80%. Chill 24 hours to -20°F for 48 hours before going into the cyclic salt spray. After one week, wash down with marine mix.

7. Every 4 weeks, remove the bolts from one panel of each of the two treatments per sealant, and remove one cover ; then, reseal as required.

NOTE: Any given cover will be removed only once every 24 weeks.

8. At the time of each 4-week inspection, document the following:

   a. Ease of removing cover plate

   b. Ease of removing old sealant, if required

   c. Ease of applying new sealant

   d. Ease of resealing unit

   e. All signs of corrosion

9. Check weekly for signs of corrosion or film failure by placing in bucket of tap water and looking for air bubbles.

10. Reporting periods are in 84-day segments from the start date of sealant application.

APPENDIX G
POLYSULFIDE SOLVENT TEST PROCEDURE

1. Materials:

   a. Three polysulfide solvents

   b. MIL-S-81733 - A&B

   c. MIL-S-8802 - A&B

   c. AMS-2267

2. Elapsed time for solvent to lift sealant at 75°F:

   a. Use bolts with sealant on them.

   b. Make panels with fillets of sealant on them.

   c. Check hourly over a 9-hour period.

3. Elapsed time for solvent to lift sealant at 55°F:

   a. Bolts with sealants.

   b. Panels with fillets of sealants.

   c. Check hourly over a 9-hour period.

4. Elapsed time for solvent to lift sealant at 35°F:

   a. Bolts with sealants.

   b. Panels with fillets of sealants.

   c. Check hourly over a 9-hour period.

APPENDIX H
CLEANER TEST PROCEDURE

1. Precorrosion of Test Panels

   a. Materials

      (1) Al 6061-T6

      (2) Coarse grit blasted surfaces

      (3) 3" x 3" x 1/8" panels

   b. Salt Spray - Marine - Kesternich Cabinet

      (1) 30-day exposure

      (2) Spray cycle:

8 hrs	Salt Spray	Mon-Fri
16 hrs	Hot Soak (95°F-95%RH)	Mon-Fri
64 hrs	Hot Soak (95°F-95%RH)	Fri-Mon

      (3) Spray with Fuel and Hydraulic Fluid Mixture

      (4) Air Dry and Store

   c. Control - Several panels will be exposed using the cyclic salt spray to determine relative surface chlorides before cleaning.

2. Test Materials Cleaner Test

   a. Control

      (1) Methyl Ethyl Ketone (MEK)

      (2) Clean, lintless cloth

      (3) Wipe down panel face

   b. Test Materials, non-etchant

      (1) Test Solvent

      (2) Clean, lintless cloth

      (3) Wipe down panel face

c. Test Materials, etchant

(1) Test Solvent

(2) Beaker

(3) Immerse panel - **lift out** - allow to work per data sheet

(4) Clean off per data sheet

d. Hot Spray Cleaners

(1) Use car spray wand

(2) Use hot water tap

(3) Spray and revise per data sheet

e. Test Conditions

(1) Chill panels to **20°F** (four panels per cleaner) overnight.

(2) Chill to a volume of the test solution to 20°F, except for the hot spray cleaners or if counterindicated by the product data sheet; then, use 40°F solvent temperature.

(3) All test specimens will be cured in a low temperature, high humidity environment.

(4) Clean two chilled panels using the chilled cleanser.

NOTE: Do not remove panels from cold box until ready for test.

(5) Clean the other chilled panel using room temperature solvent.

(6) Use insulated rubber gloves.

f. Specimen Examination

(1) Check to see if petroleum film and hydraulic fluid film removed; if yes, then

(2) Perform elemental analysis in scanning electron microscope (SEM) at 40X, 10 kilovolts, using no standards program, NOSTD.

NOTE: Prior to SEM analysis, place sample in a vacuum oven (120°F).

APPENDIX I
SUPPLEMENTAL CLEANER TEST INFORMATION

1. The self-locking nuts used to secure the bolts have the following two inherent problems which were not discovered until all tests were already in progress:

   a. Almost all the nuts are located in areas which are not accessible using only the human arm.

   b. The nuts remove all the sealant on the bolt threads.

2. The requirements generated by the problems of the self-locking nuts are:

   a. Any sealant must be able to be applied using a spray wand.

   b. The cadmium plating should be replaced by a more marine resistant coating or the bolt material changed to a more corrosion resistant metal.

3. There has been no documentation of any type as to the rate of bolt failure, rate of bolt replacement, nor have any samples of used bolts been supplied for evaluation. *It is therefore not* possible to weigh and evaluate the possible trade offs between meeting the purely technical requirements of the sealants, and meeting the user's requirements.

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